UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL

INSTITUTO DE BIOCIÊNCIAS

PROGRAMA DE PÓS-GRADUAÇÃO EM BOTÂNICA

BANCO DE SEMENTES EM CAMPOS DA PLANÍCIE COSTEIRA DO RIO GRANDE DO SUL SOB DIFERENTES MANEJOS

Mariana de Souza Vieira

Orientador: Prof. Dr. Gerhard Ernst Overbeck

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Dissertação apresentada ao Programa de Pós-Graduação em Botânica como um dos requisitos para a obtenção do grau de Mestre em Botânica pela Universidade Federal do Rio Grande do Sul

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SUMÁRIO

RESUMO GERAL

Os campos do Bioma Pampa possuem reconhecida aptidão para a pecuária extensiva devido à presença de espécies com alto potencial forrageiro. No entanto, lavouras de arroz, soja, silvicultura e até mesmo a utilização de pastagens cultivadas têm causado consideráveis impactos no Bioma Pampa e, estudos sobre restauração de áreas degradadas são escassos e merecem maior atenção. Sabe-se que o banco de sementes é relevante para a persistência de espécies vegetais em um determinado local e, para a comunidade como um todo. Um banco de sementes persistente por longo prazo tem o potencial de recompor uma área degradada mesmo que as espécies não sejam mais encontradas no local e sementes de espécies características dos diferentes estágios de sucessão da dinâmica campestre são encontradas viáveis no banco de sementes do solo. Estudos sobre banco de sementes nos Campos Sulinos são escassos e a falta de informação sobre a flora que permanece no solo após distúrbios intensos constitui um problema para avaliar o potencial de recuperação da vegetação nativa e a resiliência da vegetação. Neste contexto, esta dissertação visa colaborar com a compreensão dos possíveis rumos da vegetação campestre após distúrbios intensos.

Foram estudadas quatro áreas que representam as principais formas de uso da terra (pastagem nativa e pastagem rotativo após uso com arroz e soja) na região dos campos litorâneos no estado do Rio Grande do Sul, no sul do Brasil. Em cada área foi realizado o levantamento da composição florística ao longo de um ano e dez amostras de solo, dividido em dois estratos, foram coletadas em cada uma das áreas para o estudo do banco de sementes, em duas estações (primavera e outono). Os resultados indicam que o banco de sementes de áreas com histórico de uso intensivo possui maior riqueza, e maior similaridade com a vegetação estabelecida do que as áreas de campos naturais. Porém a maior parte das espécies que compõem a vegetação e o banco de sementes apresenta caráter ruderal e não são espécies típicas dos campos da planície costeira. Para os campos nativos pastejados, sem histórico de uso mais intensivo, o banco de sementes não parece o fator importante para a regeneração da vegetação, supondo baixa resiliência da vegetação campestre.

INTRODUÇÃO GERAL

Segundo Roberts (1981) e Csontos & Tamás (2003) foi Darwin quem fez o primeiro registo de observação de banco de sementes em 1859 ao reparar que a partir de um copo de barro retirado de uma lagoa estavam nascendo plântulas. Mas só a partir de 1970 que estudos sobre banco de sementes se tornaram mais frequentes, possibilitando a elaboração de conceitos, metodologias e classificações. Para Roberts (1981) o termo banco de sementes do solo é usado para designar o reservatório viável de sementes atual em uma determinada área de solo, já Bakker (1989) o define como reservatório correspondente às sementes não germinadas, mas potencialmente capazes de substituir as plantas adultas que tivessem desaparecido pela morte natural, por doenças, distúrbios ou consumo de animais, incluindo o homem. Segundo Templeton e Levin (1979), o banco de sementes funciona como a memória de condições ambientais passadas e da vegetação anteriormente estabelecida e seu estudo pode contribuir para a compreensão de padrões gerais de regeneração de comunidades vegetais (Fenner, 2000).

Ao chegarem à superfície do solo, as sementes podem germinar até um ano após sua dispersão, no caso das sementes transientes, ou persistirem no solo por longo período, formando o banco de sementes permanente (Thompson, 2000) que em um segundo momento, em função de um distúrbio ou variações ambientais possa vir a germinar. No entanto, existem diversas formas na literatura para classificar uma semente quanto à sua longevidade. Entre as classificações mais comumente usadas estão: *i)* a de Bakker (1989), em que as sementes das camadas mais profundas do solo são consideradas mais antigas que as sementes que se encontram próximo à superfície; *ii)* a de Thompson e Grime (1979) que propõe uma classificação baseada no período de coleta, na qual as sementes presentes no solo antes do período de chuva de sementes são consideradas persistentes; *iii)* a de Thompson (1993) que propõe uma divisão das sementes persistentes em duas classes: As que são viáveis por até cinco anos (persistentes por curto prazo) e as que persistem por um período maior que cinco anos (persistentes por longo prazo). Porém, a falta de padronização para classificação das sementes em muitos trabalhos gera muitas vezes dificuldades para a comparação entre estudos que seguem distintas classificações.

A dificuldade em categorizar as sementes se dá principalmente pela necessidade de um longo período de estudo, e alto esforço amostral, já que para classificar uma semente como persistente é preciso mais de um ano de estudo. A classificação proposta por Bakker (1989) pode ser feita de forma rápida, porém, a longevidade de uma semente pode ser classificada erroneamente se baseada apenas na informação derivada da sua profundidade do solo, pois alguns atributos das próprias sementes podem facilitar ou não a incorporação e a localização das sementes ao solo. Sementes grandes e volumosas, por exemplo, são menos facilmente incorporadas ao solo do que sementes esféricas e pequenas (Bekker *et al*., 1998).

Outro problema que surge no momento da interpretação dos dados são as diferentes metodologias aplicadas desde a forma de coleta do solo até o método usado para estimar a densidade de sementes (método da emergência ou a contagem direta de sementes). O estudo do banco de sementes através do método da emergência de plântulas tem a vantagem de considerar apenas as sementes viáveis presentes no solo. No entanto esta metodologia requer uma quantidade de tempo e espaço consideráveis já que muitas espécies emergem vagarosamente e após períodos de seca e umidade (Gross, 1990). Já o método de contagem direta de sementes proporciona resultados mais rápidos, porém exige conhecimento prévio da morfologia das sementes além de poder superestimar densidades já que não distingue as sementes inviáveis ou dormentes (Gonzalez & Ghermandi 2012).

Na região dos Campos sulinos, os ecossistemas campestres no sul do Brasil, bem como em ecossistemas campestres mais ao sul nos chamados campos do Rio de la Plata (Soriano *et al*., 1992), estudos sobre banco de sementes do solo e o seu papel ainda são muito incipientes. No sul do Brasil, o banco de sementes do solo em campos nativos foi estudados por Maia *et al.* (2003) e Favreto & Medeiros (2006) na Depressão Central, por Focht (2008) na região da campanha e por Garcia (2005) na planície costeira. Contudo, ainda faltam estudos de banco de sementes nos Campos Sulinos, e atualmente ainda é difícil chegar a conclusões gerais sobre o papel do banco de sementes para a dinâmica da vegetação campestre.

Os campos da planície costeira vêm sofrendo muito com a pressão antrópica, especialmente pelas altas taxas de transformação em outros usos (Cordeiro & Hasenack 2009). A facilidade de escoamento da produção e relevo contribuem para que áreas de campos naturais sejam convertidas em sistemas de lavoura mais rentáveis que a pecuária extensiva. O cultivo de arroz irrigado é atualmente a principal atividade agropecuária da região (Garcia, 2005). Nesse sistema de produção, o arroz é cultivado durante o verão e, a resteva (restos das plantas recentemente colhidas) acaba sendo utilizada para pecuária extensiva durante o período de pousio (Bonilha, 2013). No entanto, os bons preços da soja e as novas tecnologias têm levado os proprietários a substituírem a cultura do arroz pelo sistema de produção soja/azevém. Neste sistema, a soja é cultivada durante a primavera e o verão e após sua colheita, são introduzidas sementes de azevém para produção de pastagem e uso da terra para pecuária.

Neste contexto de conversão de áreas de campos naturais para áreas de uso intensivo, o estudo sobre o banco de sementes do solo pode dar suporte e base científica para a ecologia de restauração, já que em caso de distúrbios, a habilidade de restabelecimento natural da vegetação vem principalmente do que permanece da flora local em forma de sementes no solo.

Com o intuito de colaborar com maiores informações sobre banco de sementes do solo e poder avaliar a capacidade de resiliência de áreas campestres na planície costeira do Rio Grande do Sul a partir do banco de sementes foi desenvolvido o seguinte artigo, a ser submetido para a revista Austral Ecology: “Low resilience of subtropical grasslands in the Coastal Plain of southern Brazil: evidences from the soil seed bank”

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Low resilience of subtropical grasslands in the Coastal Plain of southern Brazil: evidences from the soil seed bank

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Abstract

The expansion of land use for agriculture is among the main reasons for the reduction of natural grasslands in coastal grasslands in subtropical southern Brazil. The aim of this study was to assess the recovery potential of grassland vegetation after land use change from the seed bank. We studied the seed bank and it relation to vegetation composition in four areas in São Lourenço do Sul, Rio Grande do Sul, Brazil with different histories of land uses and abiotic characteristics: Grassland in an area previously used for rice production; seeded grassland (seeding of *Lolium multiflorum* L.) in a rotational system with soy bean; natural grassland and natural humid grassland. We compared these areas regarding species richness, seed density and relation between seed bank and established vegetation and obtain information about the resilience in the different studied grasslands. Soil samples were collected from each area, considering to distinct soil layers (0-5 and 5-10 cm) in spring 2011 and autumn 2012. Samples were kept for a year in a greenhouse. Richness and density were estimated by the seedling emergence method. Our results show higher richness in areas with intensive land use in both seasons, high contribution of sedges and rushes and a greater similarity between seed bank and vegetation established during the spring. Most species found in soil seed bank were classified as persistent. The seed bank of areas with history of agricultural use was dominated by ruderal species that also have a high contribution in aboveground-vegetation. In natural grasslands, the dominant species in established vegetation were mostly absent in the soil seed bank. The results indicate low resilience of grassland vegetation after cultivation.

Key-words: Campos sulinos, transient seed bank, persistent seed bank, land use, established vegetation.

Introduction

With rising impacts of land use changes on biodiversity on both the regional and global scale, understanding recovery processes of vegetation after severe disturbances has become increasingly important. Land use changes have been considered to be the most important factor affecting biodiversity in this century, and grassland ecosystems are among the most impacted by land conversion (Sala et al. 2000). Land use also affects a wide range of ecosystem services and functions (White et al. 2000, Bullock et al. 2011), many of which are closely related to biodiversity (Millennium Ecosystem Assessment 2005, Perrings et al. 2010). It is expected that the world grain production will double by 2050, which constitutes a considerable challenge for sustainable land use (Cassman 1998, Tilman *et al*. 2002). Especially in those regions likely strongly affected by these transformation processes, a better understanding of the regeneration potential of natural vegetation after intensive land use and of the contribution of agricultural systems to biodiversity conservation becomes important as a basis for conservation or restoration policy and for a better integration of these with agricultural policy (Mattison & Norris 2005).

The soil seed bank represents the principal regenerative potential in areas that have suffered severe disturbances, and at the same time can be considered the memory of past environmental conditions and vegetation established previously (Bakker *et al*. 1996, Thompson, 2000). According to Bakker *et al.* (1996), the seed bank can be classified into the transient seed bank (composed of seeds that remain in the soil for less than year after their dispersion) and the persistent seed bank (formed by seeds that remain viable for more than a year after their dispersion). Obviously, it is mainly the persistent fraction of the seed bank that can determine the potential for reestablishment and the resilience of degraded vegetation (Scott & Morgan 2012), e.g. in grasslands that had been suffered severe disturbances by cultivation or other temporary changes in land use.

The species composition of the soil seed bank depends on the composition and richness of the current vegetation and of plant communities established previously. Data about similarity or dissimilarity between aboveground vegetation and seed bank can provide information about the potential of recovery of vegetation after disturbance, successional pathways after abandonment and susceptibility to biological invasions (Loydi *et al*. 2012). Additionally, seed bank data may help to evaluate whether restoration of degraded ecosystems requires seed introduction of target species as a consequence of seed limitation (e.g. Kiehl et al. 2010).

The Brazilian Pampa biome, the northern part of the large grassland region extending around the Rio de la Plata (Soriano 1992) is known for high diversity and forage potential of their grasslands (Overbeck *et al*., 2007; Boldrini, 2009; Nabinger *et al*., 2009). However, despite high potential for traditional extensive livestock, land use change is strongly affecting the region. By 2002 about 50% of the original grasslands had been converted into agricultural and silvicultural areas (Cordeiro & Hasenack 2009), and the coastal region was particularly strongly affected by land use change, with only about 15% of grasslands still considered well conserved (equivalent to approx. 2690 km^2; Cordeiro & Hasenack, 2009). In southern Brazil, the production of soy and rice is one of the most important reasons for conversion of natural areas. Rice production in southern Brazil contributes to about 54% of domestic production, with the state of Rio Grande do Sul being the largest producer. Soybeans currently are the fastest growing crop in the country. Due to new technologies, areas used previously for rice farming or extensive livestock breeding, i.e. areas previously too wet for this crop, are being increasingly transformed into soybean plantations (FARSUL 2013).

Despite the high rate of land use change, impacts of these changes on biodiversity, degradation effects and processes, and the potential for regeneration of grasslands in the Pampa Biome up to now has been addressed very poorly by research. Likewise, only very few studies of the seed bank in these grasslands exist (Favreto & Medeiros 2003, Maia et al. 2006, Garcia 2009), and even less so studies that compare the seed bank of natural grasslands without history of land use change to areas that had suffered such changes. Studies of the seed bank may contribute to a better understanding about the potential of vegetal recovery after abandonment of a former grassland area with a history of agriculture (Scott & Morgan 2012).

The aims of the present study were to (1) assess the seed bank of areas with a history of agricultural cultivation and areas that had always been used as grassland, (2) compare these areas regarding to seed bank richness, seed bank density and relation between seed bank and established vegetation and (3) discuss the resilience of natural grasslands to land use change.

Methods

Study area

The study was conducted on Cordilheira farm (1.039 ha) in the coastal plain in the extreme south of Brazil, in the municipality of São Lourenço do Sul (31º18' S and 51º58' W, average altitude 7m). Climate is humid subtropical (Cfa) with a mean annual rainfall of 1265 mm and mean annual temperature of 17.9° C (http://www.cpact.embrapa.br/agromet/estacao/normais.html, data for 1971-2000). Soils in the region are Alfisols albiqualf (Planosolos haplicos eutróficos according to the Brazilian classification; Streck *et al*. 2008) and Entisols quartzipsamments (Neossolos quartzarêncisos), with low water retention and low natural fertility (Boldrini 1997, Bonilha et al. submitted). Details on soil features of the four areas can be found in Annex 1.

Land use in Cordilheira farm can be considered typical for the region. Traditional use is livestock grazing, but in the past decades, substantial areas had been transformed into rice fields. More recently, soybean is entering in the region. It is a common practice to use areas for grazing between crop cycles, for short (less than a year, when used for soybean) or longer periods (a few years, when used for rice). Usually the cool-season grass *Lolium multiflorum* L. (ryegrass) is seeded after soybean cultivation, in order to rapidly establish a vegetation cover that can be grazed.

Four different areas were selected for our study, all of them homogeneous regarding topography:

- Grassland (30 ha) in an area that had been used for rice production for approximately fifty years and had been recovered for grazing use since six years ago (called grassland/rice” in the following).

- Seeded grassland (seeding of *Lolium multiflorum*) in a rotational system with soybean, seeded 6 month before our first sampling (24 ha). This management (soybean seeded in spring, ryegrass in autumn) had been adopted in 2009, i.e. two years before the start of our study. From October 2011 to April 2012, the established vegetation consisted exclusively of soybean (“grassland/soybean”).

- Natural grassland (9 ha) used for livestock grazing, without history of other types of use (“grazed grassland”).

- Natural grassland (8 ha) used for livestock grazing, without history of other types of use, with slightly more humid conditions than the other area (“humid grazed grassland”).

Vegetation description

The floristic composition of the established vegetation was recorded over the period of one year, from July 2011 to July 2012, by walking through each area once a month and recording all present species. Species that could not be identified *in situ* were collected for later identification at the Laboratory of Vascular Plant Systematics, Department of Botany, Institute of Biosciences (UFRGS). The full list can be found in Annex 3. In early October (before planting of soybean in one of the areas), a quantitative assessment of vegetation was conducted. Per area, 20 plots of 0.5 m² were randomly allocated. In each plot, the cover of all plant species and the percentage of bare ground were recovered using the scale proposed by Londo (1976). A detailed analysis of vegetation composition in the four areas can be found in Bonilha et al. (submitted).

Sampling of the soil seed bank

Soil samples for the seed bank study were collected in two seasons, spring (September) 2011 and autumn (April) 2012. In spring, i.e. before the period of seed rain for most species (October through March), we can expect to sample principally the persistent part of the soil seed bank, while the transient component should also be present in the autumn sample (Thompson & Grime 1979; Ortega *et al*. 1997). The samples were collected with an auger (0.5 cm in diameter and 10 cm deep). In each area soil was collected at ten points, with four samples per point, with minimum distance of 30 m between points. Points were marked by GPS at the first sampling date, and sampling was conducted at approximately the same point at the second date. The soil samples were divided into two depths (0-5 cm and 5-10 cm). The four samples from each depth were mixed for one composed sample, resulting in two composed samples per point, representing the two depth categories at each sampling data. Subsequently, the soil samples were dried for seven days and then sifted, using a 2mm mesh (Garcia 2009). Roots and plant fragments were removed in order to avoid vegetative propagation. Any large seeds that were sieved out were returned to the sample.

Seed bank assessment

Composition and seed density of the germinable seed bank were estimated using the method of seedling emergence (Thompson & Grime 1979). This method informs the number of viable seeds, while excluding nonviable seeds (Poiani & Johnson 1998). For each sampled point, 50% of the total volume collected in the field was mixed with the same amount of vermiculite (Favreto & Medeiros, 2006) and distributed into aluminum trays of 700 ml volume, thus forming a soil layer of about 2 cm (sufficient to maintain the moisture in the sample). The samples were kept in a greenhouse at Department of Forage Plants and Agrometeorology at the Faculty of Agronomy of UFRGS, under a natural temperature regime. Trays with sterile soil were distributed randomly between samples to control for possible contamination by seed rain. The samples were watered daily or every two days, depending on necessity. Emerging seedlings were identified and removed weekly. For species that could not be identified right away, at least one specimen was transplanted into a larger pot where it remained until the reproductive stage for later identification. Seedling emergence was monitored for one year for each of the two sampling data. Most taxa were identified to the species level.

Data Analysis

Density data of sampling units was transformed into seeds per square meter by multiplying the seedling numbers by a coefficient based on the surface area of sampled soil. Seed density and species number were calculated for each sample and area. Species were classified according to life cycle (perennial and non-perennial), biological type (subshrubs, sedges and rushes, herbs, and grasses), geographical origin (native or exotic) and seed bank type (transient or persistent; according the classification of Bakker *et al* 1996). For comparison of relative importance of these classes with established vegetation we used data from the quantitative assessment. Mean values of these parameters were compared between areas by randomization testing, using Euclidean distance as resemblance measure and 10.000 iterations (Pillar & Orlóci 1996).

Principal Coordinate Analysis was conducted based on the density data (using chord distance as resemblance measure). Sorensen's coefficient of similarity was used to evaluate the similarity between soil seed bank and aboveground vegetation for each area, based on both floristic (Annex 3) and quantitative vegetation data (see Bonilha et al. submitted).

Results

Seed bank

A total of 114 taxa were identified in the seed bank, 81 of them present in the spring sample and 95 in the autumn sample. A total of 9707 germinated seed (mean of 61.796 per m^2, considering all four areas) were counted in the spring seed bank, 77% of which in the upper layer. In the autumn seed bank, 4234 germinating seeds (mean of 26.954 per m^2) were recorded (64% in the upper layer). From the 114 species recorded, 86% were natives and 14% exotics. 74.2% of species were classified as 'persistent' and 25.7% as 'transient', based on their appearance in only the autumn or both the spring and autumn seed bank. The majority of the species had a perennial life cycle (64% perennial vs. 36% non-perennial).

The botanical families with major number of species present in the soil seed bank were Cyperaceae, followed by Poaceae, Asteraceae, Plantaginaceae and others. The most abundant species in spring seed bank were: *Anagallis minima* in the Grassland/Rice and Grassland/Soybean areas (22.4% and 23.9% of seedlings, respectively), and *Rhynchospora britonii* in grazed grassland and humid grassland (77.9% and 88.5%, respectively). In autumn, the most abundant species differed more among areas. *Crassula peduncularis* amounted to 32.3% of individuals in the Grassland/Rice area, *Anagallis minima* to 35.9% in the Grassland/Soybean area. The grazed grassland was characterized by high abundance of *Rhynchospora britonii* (52.7% of individuals) and humid grassland by *Axonopus affinis* (11.5%; Annex 2).

Differences in species number in the soil seed bank between areas were similar in both seasons, although values were higher for the autumn data (Fig. 1). Richness was higher in areas with present and past agricultural use when compared to areas used for traditional extensive livestock; however, differences were not always significant. For both seasons, values of richness were most similar between areas with agricultural history and between natural grasslands.

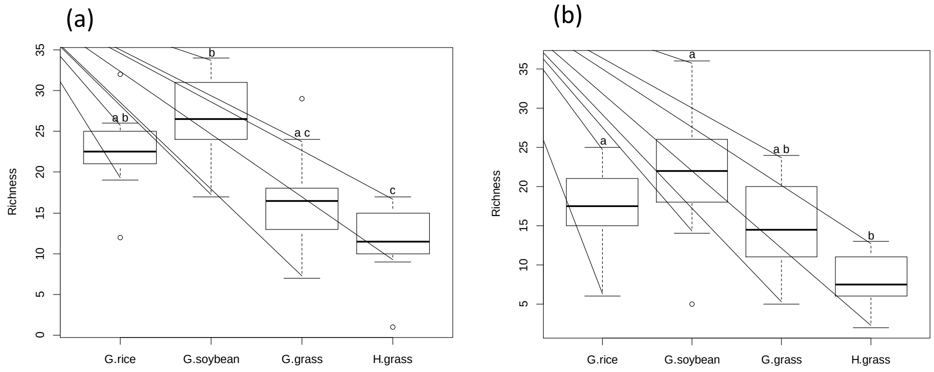

Figure 1. Species richness per area in spring seed bank (a) and autumn seed bank (b). Different letters indicate significant differences between areas

In the upper layer of the spring seed bank, the average densities in areas with a history of rice cultivation (30.991 seedlings m^{-2}) and soybean/ryegrass grasslands (29.412 seedlings m^{-2}) were lower than those in areas used only for livestock, where 59.639 seedlings m^{-2} (grazed grassland) and 71.352 seedlings m^{-2} (humid grassland) were found. Only humid grassland differed significantly ($p < 0.05$) from areas with intensive management (Fig 2). However, in the lower layer, this pattern did not hold as the humid grassland had a lower density of seeds per square meter (Fig. 2b).

In the autumn seed bank, the average density in the first 5 cm of the soil was lower than spring. We found 19.481 seeds per square meter in the grassland/rice area, 29.386 in the soybean/ryegrass area and 18.513 and 2.699 in grazed grassland and humid grassland, respectively (Fig. 2d), but only means of the soybean/ryegrass area and the humid grassland differed significantly ($p < 0.05$). In the lower layer of the soil, the greatest density of seed per square meter was found for the soybean/ryegrass area (Fig. 2e). When the densities from upper and lower layers were summed, the humid grassland had the lowest seed density among the four study areas (Fig. 2f).

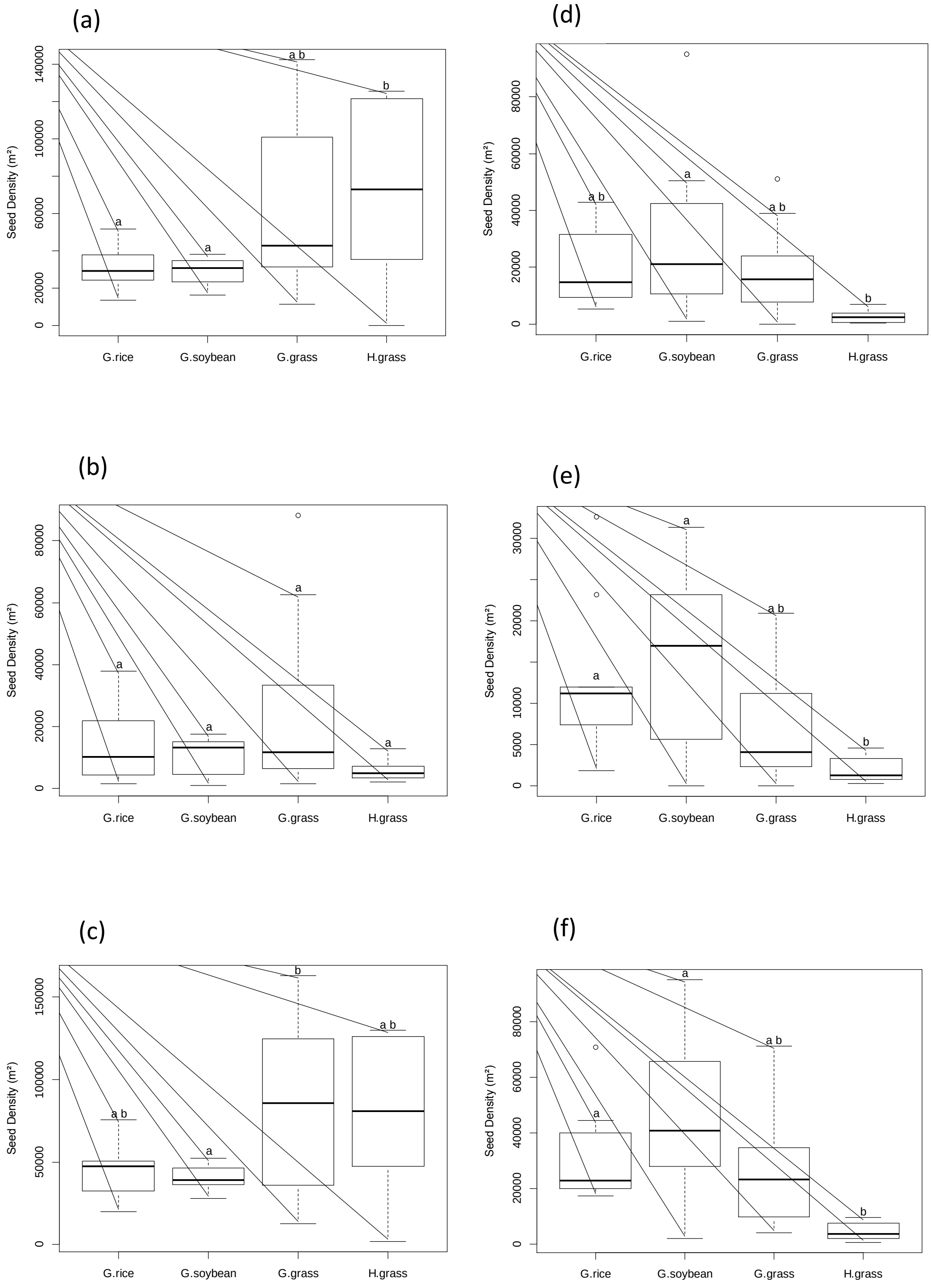

Figure 2. Seed density per area: grazed grassland – G.grass; humid grassland – H.grass; grassland/soybean – G.soybean. (a) Upper layer, spring seed bank. (b) Lower layer, spring seed bank. (c) Both layers, spring seed bank. (d) Upper layer, autumn seed bank. (e) Lower layer, autumn seed bank. (f) Both layers, autumn seed bank. Different letters indicate significant differences between areas. Please note different scales of the y-axes.

Principal coordinates analysis ordination of sample units collected in spring showed three well-defined groups. The first axis clearly separated the two grassland areas (on the left) from those with a cultivation history, while the second axis separated both areas with agricultural use (Fig 3). For the seed bank collected in autumn, i.e. with the presence of the transient component of the seed bank, the same separation of grassland and cultivated areas was found along the first ordination axis (explanation: 54,2%), but the latter were not separated from each other in the scatter diagram (Figure not shown).

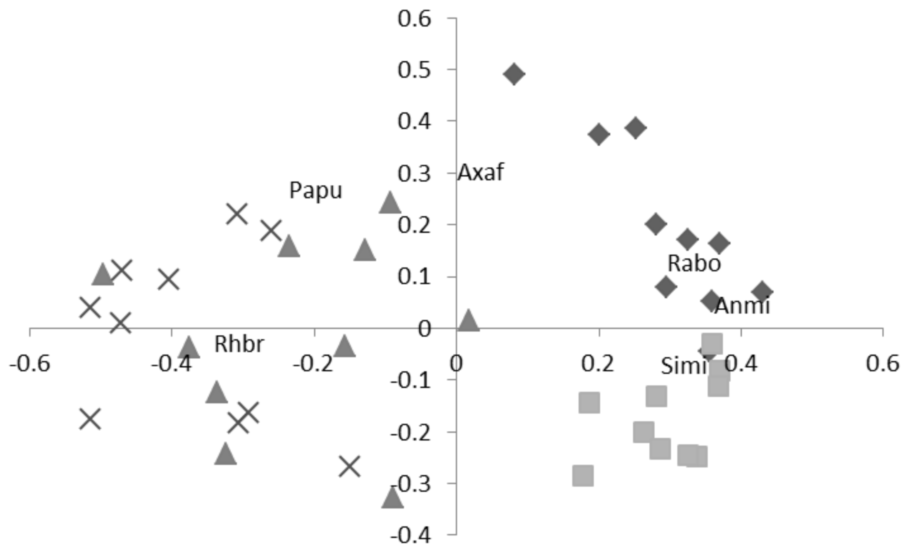

Figure 3. Ordination diagram of seed bank composition of areas under grazing and with past/present agricultural use. Explanation of the first two ordination axes: 54,2% (P= 0.4) and 11,7% (P=0.5), respectively. Legend: ◆Grassland/rice, ■ Grassland/soybean, ▲ Grazed grassland and × Humid grassland.

Similarity between seed bank and established vegetation

The number of species found in the established vegetation during the 12 months (Annex 3) of floristic research in the four areas together was 213. Of these, 36% were found in the soil seed bank. The seed bank study revealed 32 species that were not found in aboveground vegetation. 53% of the total number of species (244) were found exclusively in established vegetation and 13% exclusively in the soil seed bank. The area with a cultivation history of rice and currently used for livestock showed the highest similarity between soil seed bank and established vegetation, followed by grazed grassland, when considering data from both sampling periods. Grassland/soybean and humid grassland had the lowest similarity. The Soerensen index indicated a greater similarity between seed bank and aboveground vegetation using the seed bank data collected in autumn when compared to that collected in spring, except for the area with soybean cultivation (Tab. 1). Obviously, values were higher when using quantitative data (and not data from the floristic sampling), as a smaller part of aboveground vegetation is assessed. Using this data, high similarity of seed bank with established vegetation in the soybean/ryegrass area, which is covered by grassland only for short periods, is conspicuous (Tab.1).

Table 1. Comparison of species composition between established vegetation and seed bank in the four areas with different land use history in São Lourenco de Sul, RS, Brazil: Number of exclusive and shared species, Soerensen index based on floristic vegetation data for both sampling dates separately and Soerensen index based on quantitative vegetation data for the total seed bank data set.

	Grassland/ Rice	Grassland/ Soybean	Grazed grassland	Humid grassland
Number of species exclusively in established vegetation	56	121	59	108
Number of species exclusively in soil seed bank (both sampling dates)	35	29	40	19
Shared species between established vegetation and soil seed bank	34	40	35	35
Soerensen: Spring seed bank vs. Floristic List	0.326	0.289	0.277	0.179
Soerensen: Autumn seed bank vs. Floristic list	0.343	0.273	0.342	0.289
Soerensen: Total seed bank vs. Quantitative vegetation survey	0.460	0.840	0.433	0.374

Most of the species found in the established vegetation had a perennial life cycle (Fig 4a), unlike the soil seed bank where the proportion of species with a non-perennial life cycle (Fig 4b) was considerably higher for all areas except the soybean/ryegrass area.

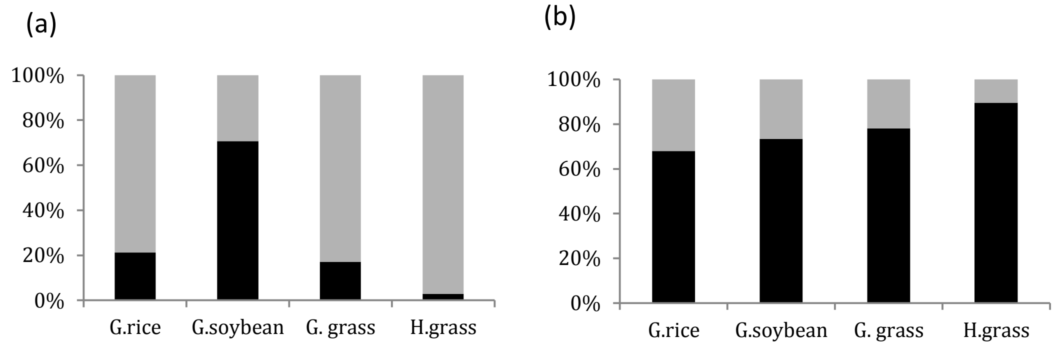

Figure 4. Percentage of species with perennial life cycle (grey) and non-perennial life cycle (black). Data based on quantitative assessment in the four study areas. (a) Established vegetation and (b) Soil seed bank.

Regarding biological type, sedges and rushes were found in higher percentage in the seed bank when compared to established vegetation, mainly in areas used only for extensive livestock. Herbs were more present in the soil seed bank in areas with intensive use (Fig. 5b). Grasses was the group with the largest representation in vegetation established, however, this group had a much lower contribution to the formation of the seed bank (Fig. 5).

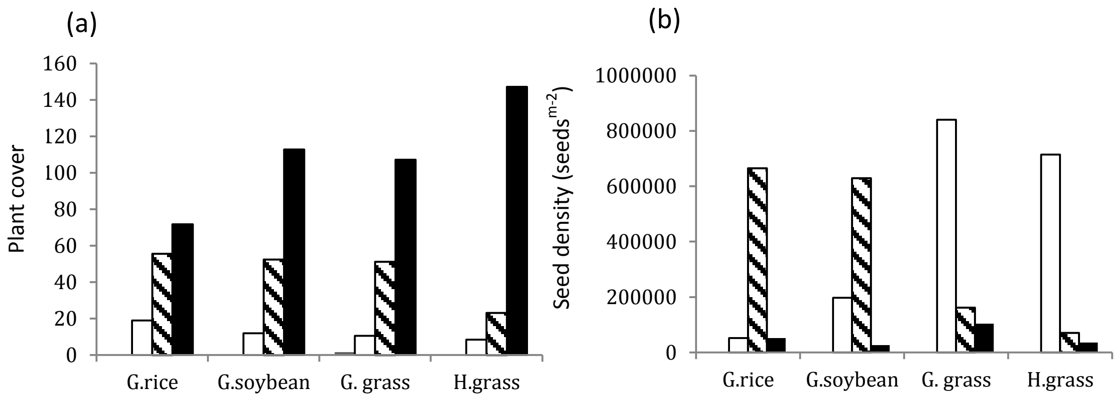

Figure 5. Percentage of species according to biological type. Subshrub (grey), sedges and rushes (white), forbs (hatched) and grasses (black). Data based on quantitative assessment in the four study areas (a) Established vegetation and (b) Soil seed bank.

In both the grassland/rice and grassland/soybean area, exotic species could be found in the established vegetation. The grassland/soybean area had high percentage of exotic species because the period in which the quantitative assessment was conducted, the area was in fallow and with *Lolium multiflorum* seeded. In both areas without historic intensive land use native species are expressively dominant in the established vegetation (Fig 6a). A greater number of exotic species was found in the soil seed bank, except for the soybean/grassland area where the number of native species was proportionally higher in the soil seed bank when compared to established vegetation.

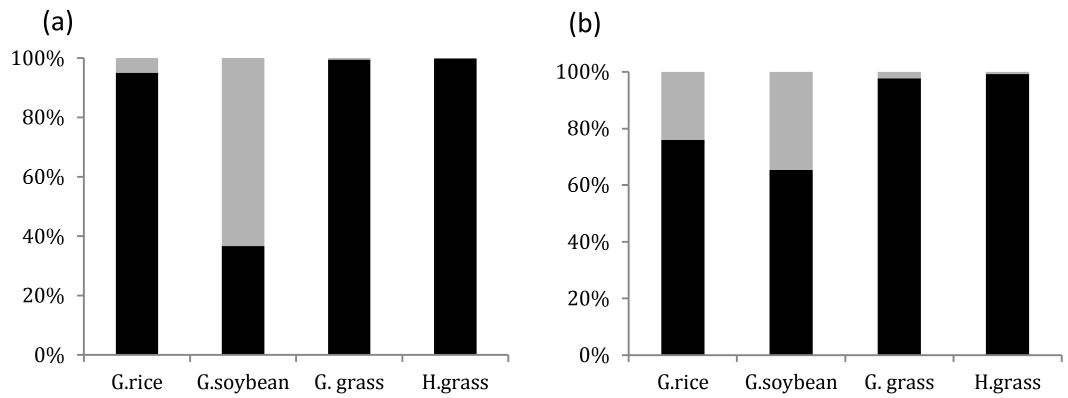

Figure 6. Percentage of species according to origin. Native (black), Exotic (grey). Data based on quantitative assessment in the four study areas. (a) Established vegetation and (b) Soil seed bank.

Discussion

Seed bank characteristics

Our study revealed considerable differences between the seed bank of the two main types of vegetation (grasslands without history of other land uses and grasslands with past or present cultivation). In both sampling seasons, the areas used only for grazing had lower species richness in the soil seed bank when compared to areas with a history of crop plantation. The more humid grassland area had the lowest richness of all areas, which agrees with other studies (Funes *et al.* 2001; Leck & Brock 2000; Ungar & Woodell 1993). This can be explained by effects of the hydrological regime and of anaerobic conditions on seed viability, reducing richness and selecting species tolerant to these conditions (Leck & Brock 2000). However, these differences between the two grazed grasslands did not reflect in strong differences in composition or in vegetation The lower richness found in the spring seed bank likely is a result of the sampling season, which assessed only the permanent fraction of seed bank. Species richness in the autumn seed bank was higher because the samples taken at this time include the transient component of the seed bank, i.e. contained seed that were incorporated into the soil seed bank after shedding of seeds in spring and summer (October through March). However, is seems possible that grassland species that produce transient seeds in low density were also present in the soil seed bank but were not assessed in the sampling (D'Angela *et al*. 1988). Also the seedling emergence method, although widely used in studies of soil seed bank may not detect the presence of dormant seeds (Gross 1990; Gonzales & Ghermandi 2012), for example seeds of Fabaceae or any other group that requires specific factors to break dormancy.

Species richness in the soil seed bank per area (69 spp. in rice and soybean areas, 75 in grazed grassland and 54 species in humid grassland) was higher than those found by Garcia (2005) in her study in coastal grassland further to the north of the coastal grasslands (39 species in grazed grassland, 61 species in area with a history of rice cultivation). However, families with greatest contribution were similar. The study by Maia *et al*. (2003), conducted in a different physiographic region of the Pampa biome, identified 122 species of seeds in the soil belonging to 25 botanical families. Cyperaceae, in this study the family with the highest number of species in the soil seed bank in the grassland areas, has been shown in several studies to be among the groups that contribute most to the formation of the soil seed bank (Boccanelli & Lewis 1994, Maia *et al*. 2003, Garcia 2005). Overall, our study revealed considerable similarity to the few other studies conducted in the *Campos sulinos* (Garcia 2005, Maia *et al*. 2003).

The upper soil layer showed higher seed density at both sampling dates, as generally observed in seed bank studies. However, in areas with past or present agricultural use, the difference in the vertical distribution of seeds was not as sharp, likely as a consequence of cultivation and associated land management practices. Although the area with history of rice plantation has been in bare fallow for six years, the high stocking rate on the site and the high percentage of bare soil in combination with high precipitation values likely causes high physical impact on the upper soil layer by trampling by animals, thus allowing for a uniformization of the seed distribution of the first 10 cm of soil (Ferreira *et al.* 2010).

Evidently, soil characteristics and resulting conditions for plant growth directly influence the choice of land use practices on different areas in the region, making it impossible to separate soil characteristics and management history in the analysis (see also Bonilha *et al.* submitted). In the case of grassland/rice and grassland/soybean areas, the higher proportion of clay in relation to areas of natural grasslands may also have influenced the soil seed bank composition.

Similarity between seed bank and established vegetation

In areas used only for grazing, the spring seed bank showed dominance of only few species and similarity between soil seed bank and established vegetation was low when compared to areas with cultivation history: a large proportion of species present in the vegetation was absent in the soil seed bank. The same pattern was observed by Scott & Morgan (2012) in semi-arid grassland in Australia. The vegetation in areas used only for grazing in southern Brazil is mostly comprised of grasses and herbs with perennial life cycle, which in general produce fewer seeds and seeds with shorter viability (Funes *et al.* 2001, Milberg 1995) and depend on resprouting from underground storage organs after biomass loss, e.g. due to grazing (Fidelis *et al.* 2009). Our data indicates that the seed bank is of little relevance for vegetation recovery after this kind of disturbances that are, in fact, inherent processes of the grassland ecosystem. This also becomes clear by comparing dominant species in seed bank and vegetation: *Rhynchospora britonii* was by far the most expressive species in the seed bank in both grassland areas, but had actually a very small contribution in aboveground vegetation (see Annex 2 and Bonilha et al. submitted).

The high similarity between established vegetation and the seed bank in disturbed environments, i.e., the areas with cultivation history, or in early stages of succession had been observed in other studies (Van der Valk & Davis 1976, Milberg & Hanson 1993, Amiaud & Touzard 2004, Scott & Morgan 2012) and is result of the high percentage of species with non-perennial life-cycle and seeds classified as persistent (Lunt 1997, López-Marino *et al.* 2000, Amiaud & Touzard 2004). Considering the clear contrast with the relation between seed bank and established vegetation in the grazed grassland, especially in the soybean/ryegrass area, this similarity thus seems to be a good indicator for degradation of the vegetation. The high seed density of ruderal species, apparently able to establish in vegetation, leads us to believe that areas with cultivation history tend to lose their original grassland characteristics (López-Marino *et al.* 2000, Bonilha 2013). Species with an annual cycle life had much lower presence in established vegetation in areas only used for pasture, which contributes to the dissimilarity between vegetation and seed bank. As the samples from spring includes only species that form a persistent seed bank, the difference between the soil seed bank and the established vegetation becomes more pronounced with this data (Amiaud & Touzard 2004). Exotic species had a considerable importance in the soil seed bank in the two areas with cultivation history, principally in the soybean/ryegrass area, where they also established abundantly, in contrast to the grassland/rice area. In the two areas without cultivation history, just a little exotic species were present in aboveground vegetation, and they could be found in major number in the soil seed bank. Most of the exotic species present at our study sites are of a rather ruderal character, but there does not seem to be a problem with invasive species at our study site.

Species richness in the autumn seed bank was higher because the samples taken at this time include the transient component of the seed bank, i.e. contained seed that were incorporated into the soil seed bank after shedding of seeds in spring and summer (October through March). Evaluation of the similarity between established vegetation and soil seed bank by calculation of the Soerensen index using both quantitative data (the vegetation sampling) and floristic data (the complete) list, per area, provided somewhat contrasting results. With data from the spring seed bank, similarity was lowest in the grazed areas. The in general higher species number in the autumn seed bank was reflected by greater similarity between vegetation and seed bank (Tab. 1), except for the grassland/soybean area: the fact that from October to April only soybean was present in aboveground vegetation in the area caused a slight decrease in the Sorensen similarity coefficient. When using quantitative data, the values obviously rise as the total number of species considered in aboveground vegetation is lower, and the soybean/ryegrass area stands out with a very high index value: in the short cycle of ryegrass grassland use, the species present in the seed bank apparently do manage to establish, which reflects the ruderal character in the vegetation. *Lolium multiflorum* itself hardly recruits from the seed bank in spring.

Conclusions: low resilience of *Campos Sulinos to severe disturbances as evidenced by the soil seed bank*

Our results indicate that regeneration potential from the soil seed bank is low in areas with a history of agricultural cultivation. The high density of persistent seed in these areas does indeed contribute to rapid establishment of vegetation cover when more intensive land use is abandoned, but the typical and dominant grassland species, especially the grasses that form the vegetation matrix, likely will not be present, as they are absent from or only very scarce in the soil seed bank which is dominated by ruderal species. Our study, together with the few other available studies of the seed bank of subtropical *Campos sulinos* grasslands in Brazil, confirms the finding that the large majority of typical grassland species depend on vegetative regrowth after a disturbance, and that regeneration from the seed bank is not the principal plant strategy. This indicates that after more severe disturbances, as the agricultural activities in our study, the vegetation likely will not return to its pre-disturbance state in unassisted recovery. It has been shown in several studies in the region that the plant species in *Campos sulinos* are adapted to disturbances like fire and grazing which – as in other grasslands around the world – can be considered to be part of their evolutionary history (Overbeck & Pfadenhauer 2006, Nabinger *et al.* 2009). On the other hand, and as shown in our study, the vegetation does not seem to be resilient to more severe disturbances such as agricultural activities, as losses of underground storage organs will mean the loss of the regeneration capacity of these grasslands (Fidelis *et al.* 2009). If degraded areas are to be restored, species introduction will thus likely be a central topic for restoration of these grasslands, which is a challenge as no experience with this exist so far in southern Brazil (Overbeck *et al.* 2013). Given the severe and long term effects of land use change on grassland composition and thus regional diversity, conservation policy should aim at limiting losses of grassland area, e.g. by establishing regional limits for transformation of grassland into agricultural areas.

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CONSIDERAÇÕES FINAIS

O presente estudo utilizou a metodologia da emergência de sementes, com amostragem em duas épocas distintas e um período de um ano para germinação para as amostras de cada um data de coleta. O método se mostrou eficaz em demonstrar diferenças entre áreas com histórico de uso distinto e permitiu a diferenciação em banco de sementes permanente e transiente. De forma geral, os resultados corroboram dados de outros estudos, embora a maior densidade de sementes encontrada neste estudo possa ser consequência de um período de estudo mais longo, como no nosso caso. Desta maneira, acreditamos que as conclusões tem uma validade geral para a vegetação campestre na região dos Campos Sulinos, ao menos para ambientes úmidos, como aqueles dominantes na planície costeira. No entanto, ainda faltam estudos em campos com solo em condições mais secas.

A vulnerabilidade dos campos do Bioma Pampa pode ser observada não apenas pela alta taxa de conversão de áreas naturais como também pelo baixo potencial de resiliência a partir do banco de sementes de áreas com histórico de uso intensivo, como indicado por nosso estudo. Além disso, a maior similaridade entre a vegetação estabelecida e o banco de sementes pode servir como indicador de área degradada, ao passo que, ao longo do processo de sucessão, as diferenças entre o banco de sementes e composição florística tendem a aumentar. De forma geral, os resultados do trabalho corroboram a perspectiva que a conservação dos campos da planície costeira do sul do Brasil está estreitamente associada à atividade pecuária e esta deve ser vista como uma aliada na preservação de áreas de planícies costeiras.

Annex 1. Soil chemical variables of the four study areas with different land use history in São Lourenco de Sul, RS, Brazil. Given are mean values from four samples per area.

	Areas			
	Grassland/Rice	Grassland/Soy-bean	Grazed grassland	Humid grazed grassland
	Alfisol albiqualf	Alfisol albiqualf	Entisol quartzipsamments	Entisol quartzipsamments
pH (H_2O)	5.32	5.22	4.62	4.57
Phosphorus (P)	6.32	11.72	8	6.15
Potassium (K^+)	63	36.75	145.5	40
Calcium (Ca^{+2})	2.35	3.3	0.8	0.9
Magnesium (Mg^{+2})	1.37	1.82	0.35	0.37
Aluminum (Al^{+3})	5.12	3.95	55.7	63.67
soil organic matter	2.22	2.27	6.67	5.75
cation exchange capacity (CEC)	6.77	8.25	16.7	12.3
CTC percent saturation by Al and bases	6.77	8.25	16.7	12.3
Particle size (%)				
Coarse sand	19	19	65	83
Fine sand	24	29	12	5
Silt	44	39	14	5
Clay	13	13	9	7

Annex 2. Seed bank density per m² per area during spring and autumn seasons of the four study areas with different land use history in São Lourenco de Sul, RS, Brazil. Given are mean values for each area. * Indicates exotic species.

		Areas							
		Grassland/ Rice		Grassland/ Soybean		Grazed grassland		Humid grassland	
		Spring	Aut.	Spring	Aut.	Spring	Aut.	Spring	Aut.
Family	Species	Seeds / m²							
Amaranthaceae	*Chenopodium ambrosioides L.*	0	25	25	25	0	25	0	0
Apiaceae	*Centella asiatica* (L.)Urb.	331	331	484	560	789	3030	127	433
	Cyclospermum leptophyllum (Pers.) Eichler	662	0	51	0	0	76	0	0
	Eryngium divaricatum Hook. & Arn.	0	560	0	0	0	0	0	0
Araliaceae	*Hydrocotyle bonariensis* Lam.	0	25	0	0	0	0	0	0
	Hydrocotyle exigua Malme	0	0	0	51	178	76	0	0
Asteraceae	Asteraceae sp.	0	51	0	0	0	0	0	25
	Baccharis trimera (Less.) DC.	0	0	0	0	0	102	0	0
	Chaptalia runcinata Kunth	0	0	0	0	102	0	0	0
	Eclipta prostrata (L.) L.	51	0	25	0	0	0	0	0
	Facelis retusa (Lam.) Sch. Bip.	306	357	255	484	51	280	0	0

	Gamochaeta sp.	51	0	51	0	0	0	51	0
	Gamochaeta americana (Mill) Weddell	560	229	560	255	509	204	76	178
	Gamochaeta coarctata (Willd.) Kerguélen	1630	280	1604	331	1146	280	1375	357
	Gamochaeta filaginea (DC.)	0	0	0	0	0	0	25	0
	Gamochaeta pensylvanica (Willd.) Cabrera	968	1095	2241	127	738	280	993	0
	Pluchea sagittalis (Lam.) Cabrera	51	0	127	25	0	0	0	0
	Senecio heterotrichius DC.	25	0	51	0	51	0	102	25
	Senecio selloi (Spreng.) DC.	0	25	0	0	0	76	0	0
	Soliva macrocephala Cabrera	76	178	535	611	25	0	0	0
	Soliva sessilis Ruiz et Pavón	0	0	0	153	0	76	0	0
	Sonchus oleraceus L.	0	0	25	0	25	255	25	0
	Symphyotrichum squamatum (Spreng.) G.L. Nesom	0	25	0	0	0	0	0	0
Campanulaceae	*Pratea hederacea* (Cham.) G. Don	0	0	25	153	0	102	0	0
	Triodanis biflora (Ruiz & Pav.) Greene	25	0	0	0	0	0	0	0
Caryophyllaceae	**Cerastium glomeratum* Thuill.	76	0	76	637	509	25	25	25

	Polycarpon tretraphyllum (L.) L.	0	51	0	0	127	204	0	0
	**Sagina procumbens* L.	5704	458	1502	433	127	0	0	0
	**Silene gallica* L.	0	0	0	0	0	25	0	0
	**Spergula arvensis* L.	0	0	0	0	25	76	0	0
Crassulaceae	*Crassula peduncularis (Sm.) Meigen*	6774	10237	2903	6239	178	102	127	127
Cyperaceae	*Bulbostylis capillaris* (L.) C.B. Clarke	102	0	382	0	1120	127	0	25
	Bulbostylis hirtella (Schrad. Ex Schult.) Nees ex Urb.	25	0	0	0	840	0	815	51
	Carex phalaroides Kunth	25	25	127	0	280	0	25	0
	Cyperaceae sp	0	0	153	0	0	178	0	127
	Cyperus aggregatus (Willd.) Endl.	357	25	1808	51	204	0	0	25
	Cyperus eragrostis Lam.	0	0	0	51	0	0	0	204
	Cyperus hermaphroditus (Jacq.) Standl.	0	51	0	0	0	25	0	76
	Cyperus reflexus Vahl	0	25	0	0	0	25	0	51
	Eleocharis bonariensis Nees	0	51	0	25	0	0	0	102
	Eleocharis flavescens (Poir.) Urb.	0	0	51	102	0	0	0	0
	Eleocharis maculosa (Vahl) Roem. & Schult.	76	0	0	0	0	0	0	25
	Eleocharis sp.	25	0	280	76	866	433	102	76

	Fimbristylis autumnalis (L.) Roem. & Schult.	204	0	1808	76	153	25	25	25
	Fimbrystilis complanata (Retz.) Link	0	51	0	127	0	25	0	0
	Fimbrystilis dichotoma (Retz.) Vahl	0	0	331	25	0	0	0	25
	Fimbrystilis sp.	0	0	51	0	0	0	0	0
	Kyllinga odorata Vahl	0	25	458	25	0	0	76	0
	Rhynchospora britonii Gale.	2445	0	5042	1146	65648	13878	68526	433
	Rhynchospora sp.	0	0	0	0	0	0	0	102
	Scirpus cernuus Vahl	102	484	76	76	0	0	51	25
Droseraceae	*Drosera brevifolia* Pursh	0	0	0	0	0	0	942	0
Euphorbiaceae	*Euphorbia pappilosa* A. St.-Hill	0	0	0	0	0	0	0	25
	Euphorbia selloi (Klotzsch & Garcke) Boiss.	0	0	25	0	0	0	0	0
Fabaceae	*Aeschynomene denticulata* Rudd.	204	51	0	0	0	0	0	0
	**Trifolium repens* L.	0	0	331	204	0	25	0	0
Haloragaceae	*Laurembergia tetrandra* (Schott ex Spreng.) Kanitz	0	0	0	0	0	127	102	153
Hypoxidaceae	*Hypoxis decumbens* L.	25	0	611	204	25	0	0	0
Iridaceae	*Sisyrinchium micranthum* Cav.	0	280	0	764	0	0	0	0
	Sisyrinchium sp.	1553	1095	3005	2063	127	433	0	25
Juncaceae	*Juncus bufonius L.*	76	484	102	6443	0	0	0	51

	Juncus capilaceus Lam.	0	0	0	25	0	0	0	0
	Juncus capitatus Weigel	0	0	0	764	0	25	0	0
	Juncus microcephalus Kunth	0	51	0	0	0	25	0	76
	Juncus tenuis Willd.	0	0	0	25	0	25	0	0
	Triglochin striata Ruiz & Pav.	0	25	0	0	0	0	0	0
Lamiaceae	*Scutellaria racemosa* Pers.	0	0	0	0	25	0	0	0
Linderniaceae	*Micranthemum umbrosum* (Walter ex J.F.Gmel.) Blake	0	0	25	0	0	0	0	0
Lythraceae	*Cuphea carthagenensis* (Jacq.) J.F. Macbr.	0	0	102	76	25	0	0	0
Malvaceae	*Sida rhombifolia* L.	0	0	51	0	0	0	0	0
Melastomataceae	*Acisanthera alsinaefolia* (DC.) Triana	0	0	0	0	0	76	25	0
Menyanthaceae	*Nymphoides indica* (L.) Kuntze	25	25	0	0	0	76	0	25
Molluginaceae	*Mollugo verticiliata* L.	25	0	0	25	0	0	0	0
Onagraceae	*Ludwigia decurrens* Walter	0	102	102	0	0	0	0	0
Oxalidaceae	*Oxalis conorrhiza* Jacq.	1070	102	1553	204	1222	102	968	51
Plantaginaceae	*Gratiola peruviana* L.	917	1273	637	2190	331	866	0	0
	Plantago myosurus Lam.	25	0	0	0	0	51	0	0
	Plantago penantha Griseb.	0	0	0	331	0	25	0	0
	Plantago tomentosa Lam.	51	0	0	0	0	0	0	0
	**Scoparia dulcis* L.	0	153	0	51	0	76	0	0

	Stemodia verticiliata (Mill.) Hassl.	0	0	306	0	51	0	0	0
Poaceae	*Axonopus affinis* Chase	3158	357	25	25	891	535	102	535
	**Briza minor* L.	0	0	0	25	0	0	0	0
	Bulbostylis sp	153	280	0	0	51	51	306	25
	**Cynodon dactylon* (L.) Pers.	25	0	25	0	0	0	0	0
	Dichanthelium sabulorum (Lam.) Gould & C.A. Clark	0	127	0	0	229	509	76	127
	Digitaria aequiglumis (Hack. & Arechav.) Parod	0	0	0	0	0	25	0	25
	Eragrostis bahiensis Schrad. ex Schult.	0	0	0	0	25	102	25	25
	Eragrostis cataclasta Nicora	255	0	0	0	153	204	51	25
	Eragrostis lugens Nees	0	0	0	0	0	25	51	0
	**Lolium multiflorum* L.	0	0	178	1783	0	51	0	331
	Panicum aquaticum Poir.	535	0	0	0	76	0	0	0
	Panicum dichotomiflorum Michx.	0	25	0	0	0	0	0	0
	Paspalum dilatatum Poir.	0	0	0	25	0	306	0	51
	Paspalum notatum A. H. Liogier ex Flügge	0	25	0	0	0	153	25	153
	Paspalum pumilum Nees	382	0	25	0	6570	357	1579	306
	**Poa annua* L.	25	76	255	51	0	0	0	0
	Poaceae sp	102	0	0	204	25	25	51	0

	Steinchisma hians (Elliott) Nash	0	0	0	0	51	51	0	0
	* *Vulpia australis* (Nees ex Steud.) C. H. Blom	0	51	0	0	0	0	0	0
Portulacaceae	*Portulaca oleracea* L.	0	0	25	0	25	0	0	0
Primulaceae	**Anagallis minima* (L.) Krause	10135	8072	9575	15788	586	509	127	102
Ranunculaceae	*Ranunculus bonariensis* Poir.	5526	3820	1477	1451	0	968	25	0
Rubiaceae	*Oldenlandia salzmannii* (DC.) Benth. & Hook. f. ex B.D. Jacks.	407	509	535	484	0	51	0	0
	Richardia brasiliensis Gomes	25	0	25	0	51	0	0	0
	Richardia stellaris (Cham. & Schltdl.) Steud.	0	0	0	0	0	25	0	0
Scrophulariaceae	**Linaria texana* Scheele	0	0	0	0	25	331	76	0
Solanceae	*Schwenckia curviflora* Benth.	0	0	0	0	0	25	0	0
	Solanum americanum Mill.	0	25	0	25	0	0	0	0
Verbenaceae	*Glandularia selloi* (Spreng.) Tronc.	0	51	25	0	0	25	0	0
NI	Sp. 1	0	0	0	0	25	0	229	0
	Sp. 2	0	0	0	0	0	0	102	0
	Sp. 3	0	0	0	0	0	25	0	0
	Sp. 4	0	0	0	25	0	0	0	0

Annex 3: Floristic List of species found in the established vegetation during the 12 months for the four study areas with different land use history in São Lourenco de Sul, RS, Brazil. Number 1 Indicates presence, number 0 absence and * Indicates exotic species. From Bonilha et al. (submitted).

	Família/Espécie	**grassland/ soybean**	**grassland/ rice**	**grazed grassland**	**humid grassland**
Amaranthaceae	*Alternanthera philoxeroides* (Mart.) Griseb.	1	0	1	1
	Chenopodium haumanii Ulbr.	0	0	0	1
	Gomphrena celosioides Mart.	0	0	1	0
	Gomphrena perennis L.				
	Pfaffia tuberosa Hicken	1	0	0	1
Alismataceae	*Echinodorus longiscapus* Arech.	1	0	1	1
Apiaceae	*Bowlesia incana* Ruiz & Pav	0	0	0	1
	Cyclospermum leptophyllum (Pers.) Eichler	1	1	1	1
	Centella asiatica (L.)Urb.	1	1	1	1
	Eryngium divaricatum Hook. & Arn.	1	1	1	0
	Eryngium elegans Cham. & Schltdl.	1	0	1	1
	Eryngium horridum Malme	1	0	0	1
	Eryngium pandanifolium Cham. & Schltdl.	1	0	0	1
Apocynaceae	*Oxypetalum tomentosum* Wight ex Hook. & Arn.	0	0	0	1
Araliaceae	*Hydrocotyle bonariensis* Lam.	1	1	1	1
	Hydrocotyle exigua Malme	1	0	1	1
	Hydrocotyle cryptocarpa Speg.	0	0	1	0
Asteraceae	*Acanthospermum australe* (Loefl.) Kuntze	1	0	1	1
	Baccharis milleflora DC.				
	Baccharis riograndensis I.L. Teodoro & J.E. Vidal	1	0	0	1
	Baccharis genistelloides subsp. crispa (Spreng.) Joch. Müll.	1	1	1	1
	Chaptalia runcinata Kunth	1	0	1	1
	**Coleostephus myconis* (L.) Cass.	1	1	0	0
	Conyza blakei (Cabr.) Cabrera	1	0	0	1

	Conyza bonariensis (L.) Cronquist (1943)	1	0	1	1
	Conyza chilensis Spreng	1	1	1	0
	**Crepis capillaris* (L.) Wallr.	0	0	0	0
	Eclipta prostrata (L.) L.	1	0	0	1
	Elephantopus mollis Kunth	1	0	1	1
	Erectites hieracifolius (L.) Raf. Ex DC.	0	1	0	1
	Facelis retusa (Lam.) Sch. Bip.	1	1	0	0
	Noticastrum calvatum (Baker) Cuatrec.	1	0	0	1
	Gamochaeta americana (Mill) Weddell	1	1	1	1
	Gamochaeta coarctata (Willd.) Kerguélen	1	1	0	0
	Gamochaeta falcata (Lam.) Cabrera	0	1	0	0
	Gamochaeta filaginea (DC.)	0	1	1	0
	Hypochaeris chillensis (Kunth) Britton	1	1	0	1
	**Hypochaeris glabra* L.	1	1	0	1
	Hypochaeris lutea (Vell.) Britton	1	1		1
	Hypochaeris megapotamica Cabrera	1	1	0	1
	Hypochaeris neopinnatifida Azevêdo-Gonç & Matzenb.	1	1	0	1
	Micropsis spathulata (Pers.) Cabrera	1	1	0	0
	Eupatorium tweedieanum Hook. & Arn.	0	0	1	0
	Orthopappus angustifolius (Sw.) Gleason	0	0	1	1
	Pluchea oblongifolia DC.	1	1	0	1
	Pluchea sagittalis (Lam.) Cabrera	1	0	1	1
	Pterocaulon alopecuroides (Lam.) DC.	1	0	0	1
	Pterocaulon angustifolium DC.	1	0	0	1
	Pterocaulon cordobense Kuntze	1	0	0	1
	Pterocaulon polystachyum DC.	1	0	0	1
	Senecio heterotrichius DC.	1	0	0	1
	**Senecio madascariensis* Poir	0	1	0	0
	Senecio selloi (Spreng.) DC.	1	0	1	1
	Soliva macrocephala Cabrera	0	1	1	0

	Soliva sessilis Ruiz & Pav.	1	1	1	0
	Stenachaenium megapotamicum Baker	1	0	0	1
	Symphyotricum squamatum (Spreng.) G.L. Nesom	1	1	1	1
Boraginaceae	**Echinum plantagineum* L.	0	1	0	0
	Varronia curassavica Jacq.				
Brassicaceae	**Lepidium aletes* Macbride (1934)	0	1	0	0
Cactaceae	*Opuntia monacantha* Haw.	0	0	1	0
Campanulaceae	*Pratia hederacea* Cham.	1	1	1	1
	Triodanis biflora (Ruiz & Pav.) Greene	0	0	0	0
Calyceraceae	*Acicarpha procumbens* Less.	1	0	0	1
Caryophyllaceae	**Cardionema ramosissimum* (Weinm.) A. Nelson & J.F. Macbr.	1	0	0	1
	**Cerastium glomeratum* Thuill.	1	1	1	0
	Cerastium humifusum Camb.	1	1	0	0
	**Drymaria cordata* (L.) Willd. ex Roem. & Schult	1	1	0	0
	Sagina chilensis Naudin	1	1	1	1
	**Silene galica* L.	1	1	0	0
	**Stellaria media* (L.) Vill.	1	1	0	0
	**Spergula arvensis* L.	1	1	0	0
Commelinacaceae	*Commelina erecta* L.	0	0	0	1
Convolvulaceae	*Dichondra sericea* Sw.	1	0	1	1
Cyperaceae	*Bulbostylis cf. capillaris* (L.) C.B. Clarke	1	0	0	1
	Cyperus aggregatus (Willd.) Endl.	1	0	1	1
	Cyperus eragrostis Lam.	0	0	1	0
	Cyperus haspan L.	1	0	0	0
	Pycreus polystachyos (Rottb.) P. Beauv.	1	1	1	1
	Cyperus reflexus Vahl	0	0	0	1
	Cyperus rigens J. Presl & C. Presl	1	0	0	1
	**Cyperus iria* L.	0	0	1	0
	Cyperus hermaphroditus (Jacq.) Standl.	0	0	1	0
	Eleocharis bonariensis Nees	1	1	1	1

	Eleocharis maculosa (Vahl) Roem. & Schult.	1	0	0	1
	Eleocharis minima Kunth	1	1	1	1
	Eleocharis montana (Kunth) Roem. & Schult.	1	0	1	0
	Eleocharis sellowiana Kunth	1	1	0	1
	Eleocharis viridans Kük. ex Osten	1	1	0	1
	Fimbristylis autumnalis (L.)	1	1	0	0
	Kyllinga odorata Vahl	1	1	1	1
	Kyllinga vaginata Lam	1	1	0	0
	Rhynchospora barrosiana Guagl.	1	1	1	1
	Rhynchospora tenuis Willd. ex Link	1	0	1	1
	Rhynchospora holoschoenoides (Rich.) Herter	1	0	1	1
	Rhynchospora praecincta Maury ex Micheli	1	0	1	0
	Scirpus cernuus Vahl (1805)	1	0	0	0
	Scleria distans Poir.	1	0	0	1
Droseraceae	*Drosera brevifolia* Pursh	1	1	0	1
Euphorbiaceae	*Euphorbia pappilosa* A. St.-Hill	1	0	0	1
	Euphorbia selloi (Klotzsch & Garcke) Boiss.	0	0	1	0
Eriocaulaceae	*Eriocaulon modestum* Kunth	1	0	0	1
Fabaceae	*Aeschynomene denticulata* Rudd.	0	0	1	0
	Desnodium adscendens (Sw.) DC.	1	0	0	1
	Desmodium barbatum (L.) Benth	1	0	0	1
	Desmodium incanum DC.	1	1	0	1
	Macroptilium prostratum (Benth.) Urb.	1	0	0	1
	Macroptilium psammodes (Lindm.) S. I. Drewes & R. A. Palacios	1	0	0	0
	**Medicago lupulina* L.	0	1	0	0
	Stylosanthes montevidensis Vogel	1	0	0	1
	Stylosanthes viscosa (L.) Sw.	1	0	0	1
	**Trifolium repens* L.	0	1	1	0
Gentianaceae	*Schultesia australis* Griseb.	0	0	0	1
Haloragaceae	*Laurembergia tetrandra* (Schott ex Spreng.) Kanitz	1	0	0	1

Hypericaceae	*Hypericum* sp.	0	0	1	0
Hypoxidaceae	*Hypoxis decumbens* L.	1	1	0	1
Iridaceae	*Sisyrinchium micranthum* Cav.	1	1	1	1
	Sisyrinchium c.f. vaginatum Spreng.	0	1	0	0
Juncaceae	*Juncus bufonius* L.	1	1	1	1
	Juncus dichotomus Elliott	1	1	1	1
	Juncus microcephalus Kunth	1	1	1	1
Juncaginaceae	*Lilaea scilloides* (Poir.) Hauman	0	0	1	0
Lamiaceae	*Hyptis mutabilis* (Rich.) Briq.	0	0	1	1
	Scutellaria racemosa Pers.	1	1	0	1
Lentibulariaceae	*Utricularia* cf. *tridentata* Sylvén	1	0	0	1
	Utricularia cf. *laxa* St. Hilaire & Girard	1	0	0	1
Lycopodiaceae	*Lycopodiella alopecuroides* (L.) Cranfill	1	0	0	1
Lythraceae	*Cuphea carthagenensis* (Jacq.) J.F. Macbr.	1	0	0	1
	Cuphea glutinosa Cham. & Schltdl.	1	1	1	1
	Lythrum hyssopifolia L.	1	0	1	1
Malvaceae	*Sida rhombifolia* L.	1	1	1	1
Marsileaceae	*Regnellidium diphyllum* Lindm.	1	0	0	0
Melastomataceae	*Acisanthera alsinaefolia* (DC.) Triana	1	0	0	1
	Tibouchina asperior (Cham.) Cogn.	1	0	0	1
	Tibouchina gracilis (Bonpl.) Cogn.	0	0	0	1
Menyanthaceae	*Nymphoides indica* (L.) Kuntze	1	1	1	1
Onagraceae	*Ludwigia hexapetala* (Hook. & Arn.) Zardini, H. Gu & P.H. Raven	0	1	0	0
Orchidaceae	*Habenaria parviflora* Lindl.	1	0	0	1
Orobanchaceae	*Agalinis communis* (Cham. & Schltdl.) D'Arcy	1	0	0	1
	Buchnera longiflora Arn.	1	0	0	1
Ophioglossaceae	*Ophioglossum crotalophoroides* Walter	1	1	0	0
Oxalidaceae	*Oxalis debilis* Kunth	1	1	0	0
	Oxalis perdicaria (Molina) Bertero	1	1		0
	Oxalis brasiliensis G. Lodd.	1	1	0	0
Plantaginaceae	*Bacopa lanigera* Wettst.	1	0	0	1
	Bacopa monnieri (L.) Wettst.	1	0	1	1

	Callitriche deflexa A. Braun ex Hegelm.	0	1	0	0
	Gratiola peruviana L.	1	1	1	1
	**Linaria texana* Scheele	1	0	0	1
	Plantago catharinea Decne.	0	1	0	0
	Plantago myosuros Lam.	1	1	0	1
	**Scoparia dulcis* L.	1	0	1	0
Poaceae	*Agrostis montevidensis* Spreng. ex Nees	1	0	1	1
	Andropogon lateralis Nees	1	0	1	1
	Andropogon selloanus (Hack.) Hack.	1	0	0	1
	Axonopus affinis Chase (1938)	1	1	1	1
	**Briza minor* L.	0	1	0	1
	Chascolytrum poomorphum (J. Presl) L. Essi, Longhi-Wagner & Souza-Chies	0	1	1	0
	Chascolytrum uniolae (Nees) L. Essi, Longhi-Wagner & Souza-Chies	1	0	1	1
	Chascolytrum rufum J. Presl	0	0	0	0
	**Cynodon dactylon* (L.) Pers.	1	1	1	0
	Dichanthelium sabulorum (Lam.) Gould & C.A. Clark	1	1	1	1
	Digitaria eriostachya Mez	1	0	1	1
	Eleusine indica (L.) Gaertn.	0	1	1	0
	Eragrostis bahiensis Schrad. ex Schult.	1	0	1	1
	Eragrostis cataclasta Nicora	1	0	1	1
	Eragrostis neesii Trin.	1	0	1	1
	**Eragrostis plana* Nees	0	1	1	0
	Eragrostis polytricha Nees	1	0	1	1
	Ischaemum minus J. Presl	1	1	1	1
	Luziola peruviana Juss. ex J.F. Gmel.	0	1	0	1
	**Lolium multiflorum* Lam.	0	1	1	0
	**Melinis repens* (Willd.) Zizka	1	1	1	1
	Panicum dichotomiflorum Michx.	1	0	1	1
	Panicum aquaticum Poir.	1	0	0	1
	Paspalum hyalinum Nees ex Trin.	1	0	0	1
	Paspalum dilatatum Poir.	1	0	0	1
	Paspalum lepton Schult.	1	0	1	1
	Paspalum notatum A. H. Liogier ex Flüggé	1	0	1	1

	Paspalum pauciciliatum (Parodi) Herter	1	0	0	1
	Paspalum pumilum Nees	1	1	1	1
	Paspalum urvillei Steud.	1	1	0	1
	Paspalum vaginatum Sw.	0	0	0	1
	Piptochaetium montevidense (Spreng.) Parodi	1	0	1	1
	**Poa annua* L.	1	1	1	1
	Polypogon chilensis (Kunth) Pilg.	0	0	1	1
	Sacciolepis vilvoides (Trin.) Chase	1	1	1	1
	Schizachyrium microstachyum (Desv. ex Ham.) Roseng., B.R. Arrill. & Izag.	1	0	0	1
	Setaria parviflora (Poir.) Kerguélen	1	1	1	1
	Sporobolus indicus (L.) Br.	1	1	1	1
	Steinchisma decipiens (Nees ex Trin.) W.V. Br.	1	0	1	1
	Steinchisma hians (Elliott) Nash	1	0	1	1
	**Vulpia bromoides* (L.) Gray	0	1	1	0
Polygonaceae	*Polygonum punctatum* Elliott	1	0	0	1
Polygalaceae	*Monnina stenophylla* A. St.-Hil.	1	0	0	1
	Polygala duarteana A. St.-Hil. & Moq.	1	0	0	1
	Polygala pulchella A. St.-Hill. & Moq	0	0	0	0
Ranunculaceae	*Ranunculus bonariensis* Poir.	1	1	0	1
Primulaceae	**Anagallis minima* L. (1753)	1	1	1	0
Rubiaceae	*Spermacoce verticillata* L.				
	Galium humile Cham. & Schltdl.	1	0	0	1
	Richardia brasiliensis Gomes	1	0	1	1
	Richardia stellaris (Cham. & Schltdl.) Steud.	1	0	1	1
	Oldenlandia salzmannii (DC.) Benth. & Hook. f. ex B.D. Jacks.	1	0	1	0
Solanaceae	*Schwenckia curviflora* Benth.	1	0	0	1
	Solanum sisymbriifolium Lam.	0	1	0	0
	Solanum americanum Mill.	1	1	0	1
	Solanum viarum Dunal	1	0	0	0

	Petunia integrifolia (Hook.) Schinz & Thell.	1	0	0	1
Sphagnaceae	*Sphagnum* sp.	0	0	0	1
Verbenaceae	*Glandularia selloi* (Spreng.) Tronc.	1	1	0	1
	Verbena montevidensis Spreng.	1	1	1	0
Xyridaceae	*Xyris jupicai* Rich.	1	0	0	1